Announcements

- FINAL EXAM:
  - PHYS 132-001: Wednesday, May 10 @ 10-11:50 am
- Homework for tomorrow…

  Ch. 23, Probs. 14, 16, 18, & 53

  CQ3: a) nothing b) no image

  23.4: 5.4 m

  23.8: 42°

  23.9: 4.33 m
- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm
- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 23

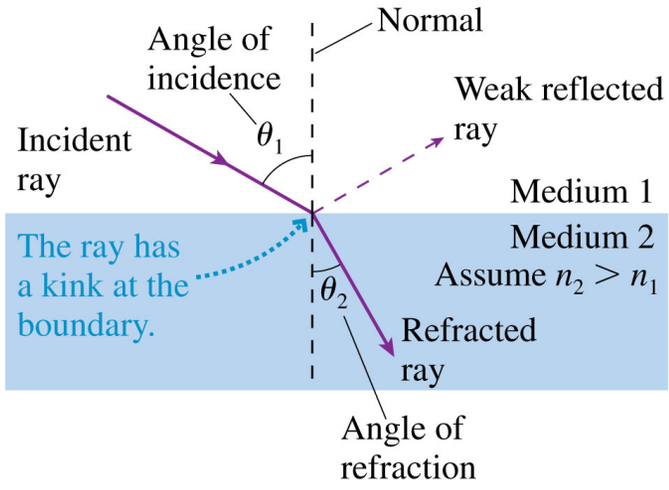
Ray Optics

(Refraction)

Last time...

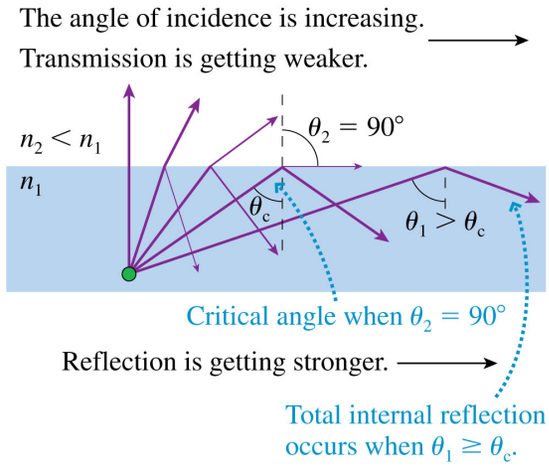
- *Snell's Law* is...

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$



- *Critical Angle,* θ_c, for *Total Internal Reflection...*

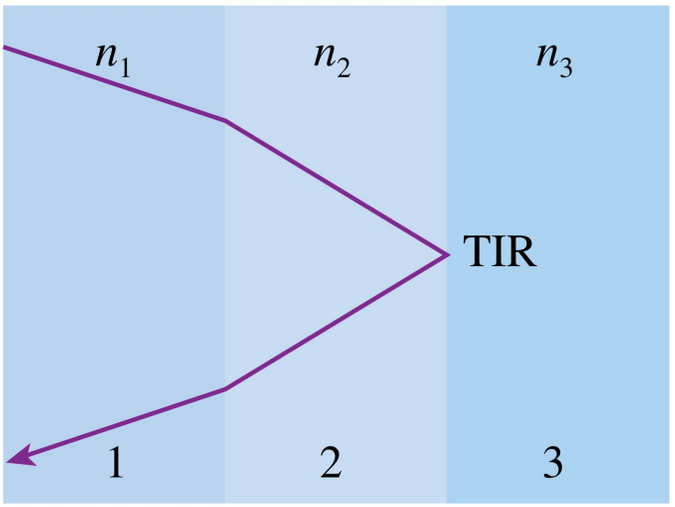
$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$



Quiz Question 1

A laser beam undergoes two refractions plus total internal reflection at the interface between medium 2 and medium 3.

Which is true?

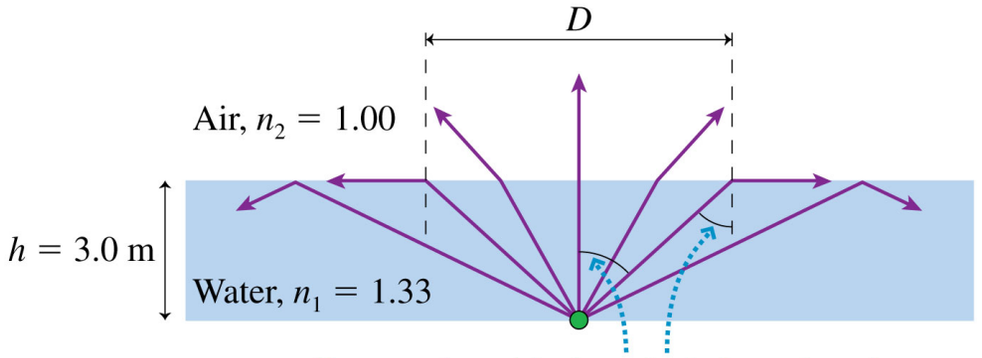


1. $n_1 < n_3$.
2. $n_1 > n_3$.
3. There's not enough information to compare n_1 and n_3.

i.e. 23.5: Total internal reflection

A light bulb is set in the bottom of a 3.0 m deep swimming pool.

What is the diameter of the circle of light seen on the water's surface from above?



Rays at the critical angle θ_c form the edge of the circle of light seen from above.

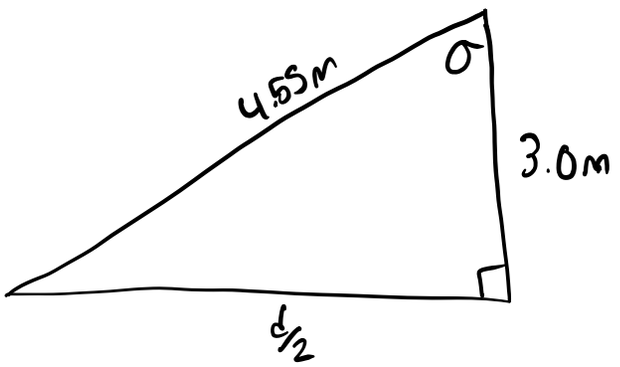
$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\theta_1 = \theta_c \quad \theta_2 = 90^\circ$

$n_1 \sin\theta_c = n_2$

$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

$\theta_c = 49^\circ$



$\cos\theta = \frac{A}{H}$

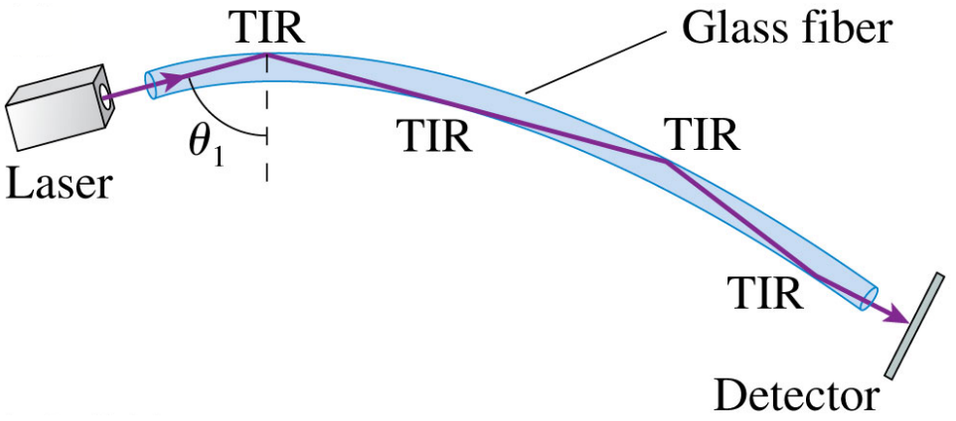
$H = \frac{A}{\cos\theta}$

$d/2 = 3.42$

$d = 6.8\text{m}$

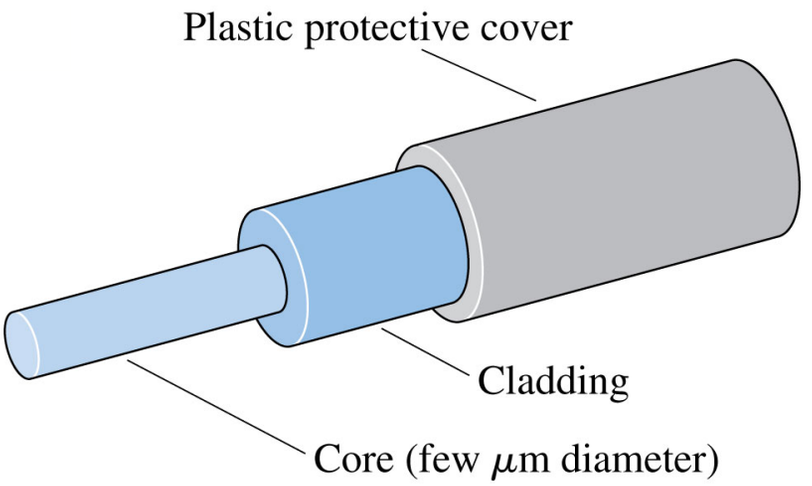
Fiber Optics…

- The most important modern application of *total internal reflection* (TIR) is *optical fibers*.
- Light rays enter the glass fiber, then impinge on the inside wall of the glass at an angle above the critical angle, so they undergo TIR and remain inside the glass.
- The light continues to "bounce" its way down the tube as if it were inside a pipe.



Fiber Optics…

- In a practical optical fiber, a small-diameter glass core is surrounded by a layer of *glass cladding*.
- The glass used for the core and the cladding have:
  - $n_{\text{core}} > n_{\text{cladding}}$



23.4:
Image Formation by Refraction

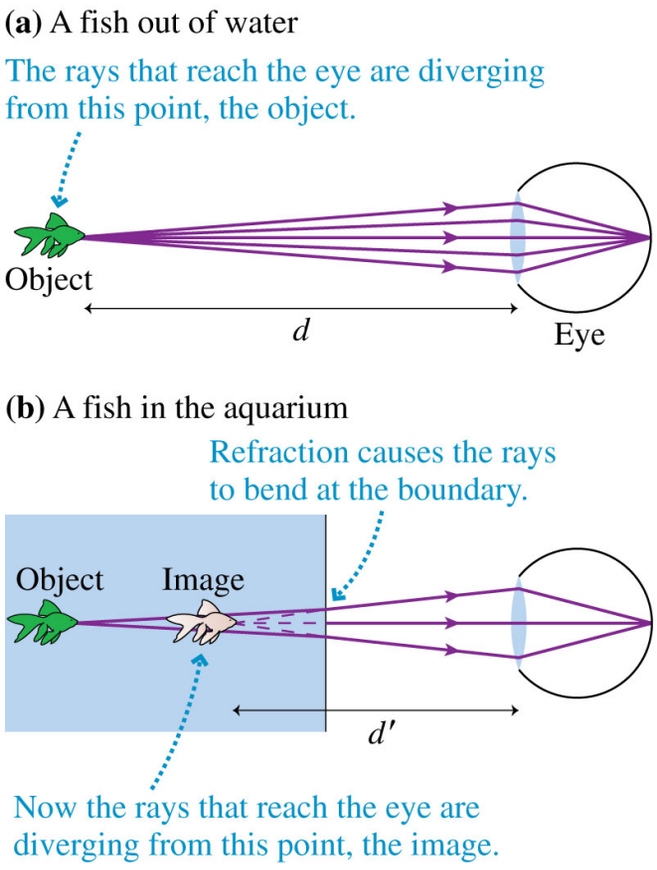
Q: If you see a fish that appears to be swimming close to the front of an aquarium, but then look through the side, you'll find that the fish is actually *farther* than you thought.

Why?

23.4: Image Formation by Refraction

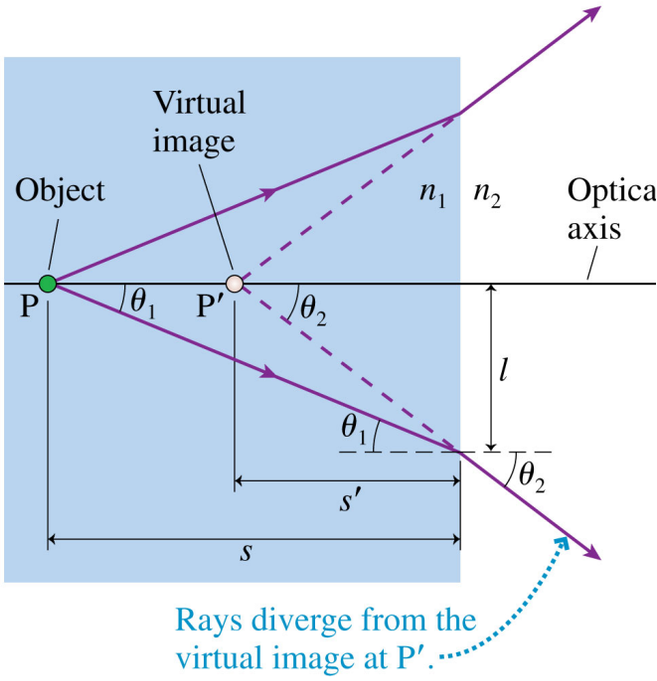
Q: If you see a fish that appears to be swimming close to the front of an aquarium, but then look through the side, you'll find that the fish is actually *farther* than you thought. Why?

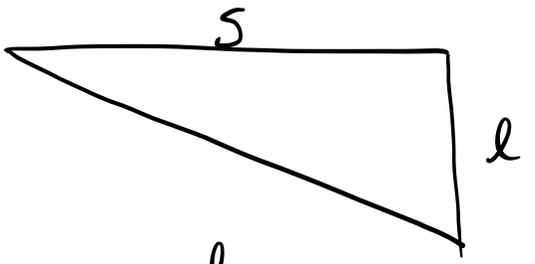
A: *Refraction* of light at the boundary!



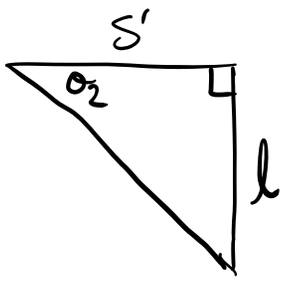
23.4: Image Formation by Refraction

What is the *image distance*, *s'*, in terms of the *object distance*, *s*, as measured from the boundary?





$$\tan\theta_1 = \frac{l}{s} = \theta_1$$



Small angle approx.

$$\tan\theta_2 = \frac{l}{s'} = \theta_2$$

$$l = s\theta_1 = \theta_2 s'$$

$$\frac{\theta_1}{\theta_2} = \frac{s'}{s}$$

Snells law

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_1\theta_1 = n_2\theta_2$$

$$\frac{\theta_1}{\theta_2} = \frac{n_2}{n_1}$$

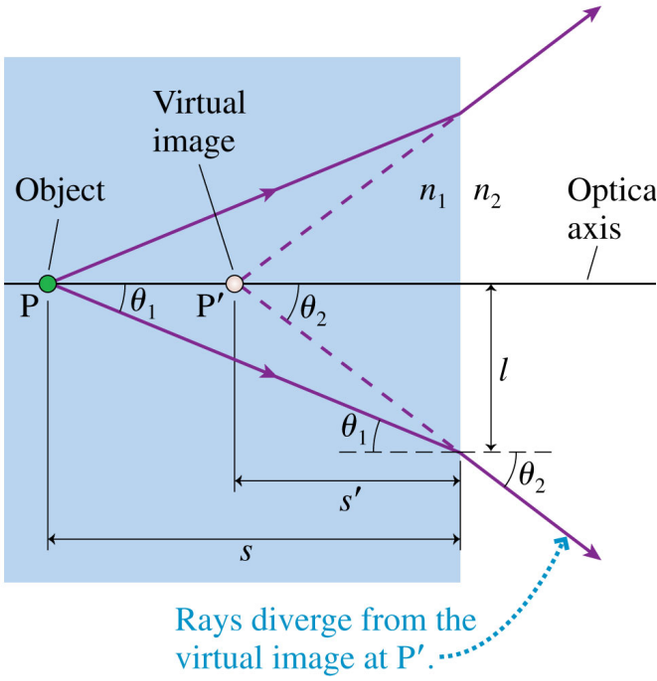
$$\frac{n_2}{n_1} = \frac{s'}{s}$$

$$s' = \left(\frac{n_2}{n_1}\right)s$$

23.4: Image Formation by Refraction

What is the *image distance*, *s'*, in terms of the *object distance*, *s*, as measured from the boundary?

$$s' = \frac{n_2}{n_1} s$$



Notice:

n_2 is the index of refraction of the material that the light ray is *transmitted* into.

Quiz Question 2

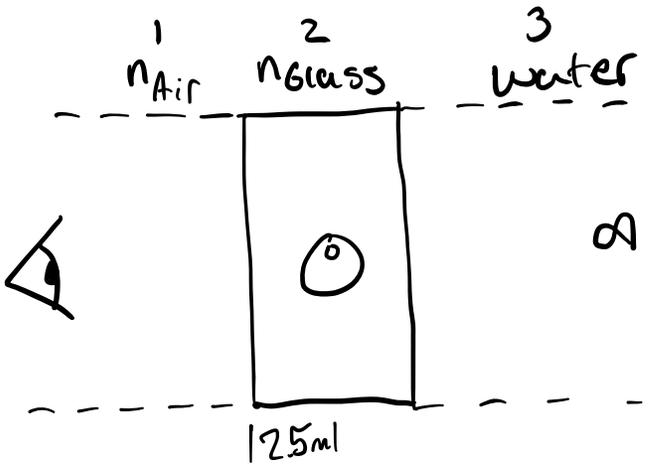
A fish in an aquarium with flat sides looks out at a hungry cat. To the fish, the distance to the cat appears to be

1. *less* than the actual distance.
2. *equal* to the actual distance.
3. *more* than the actual distance.

i.e. 23.6
An air bubble in a window

A fish and a sailor look at each other through a 5.0 cm thick glass porthole in a submarine. There happens to be an air bubble right in the center of the glass.

How far behind the surface of the glass does the air bubble appear to the fish? To the sailor?

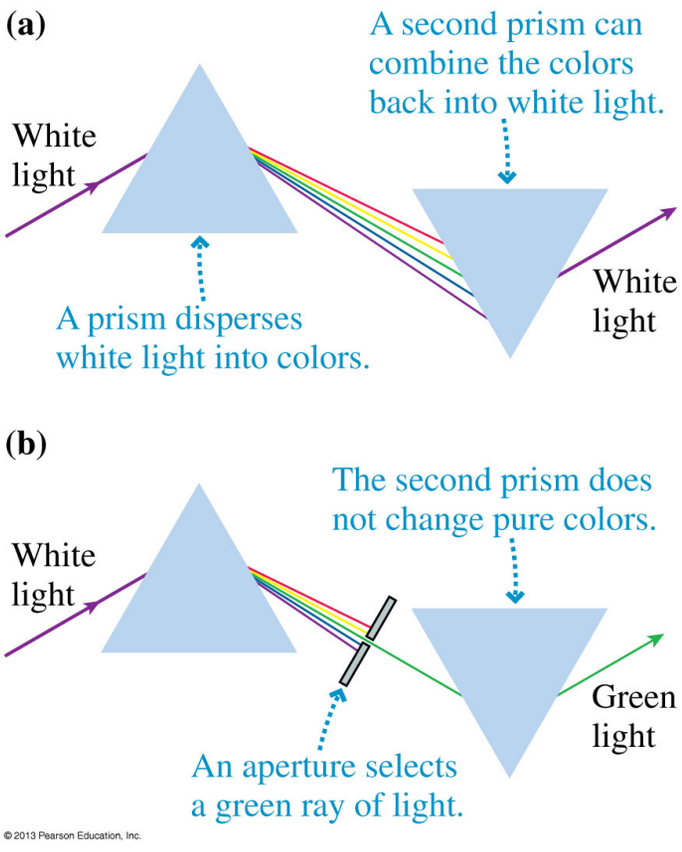


$$S' = \frac{n_3}{n_2} S = \frac{1.33}{1.50}(2.5cm) = 2.2cm$$

$$S' = \frac{n_1}{n_2} S = \frac{1.00}{1.50}(2.5cm) = 1.7\,cm$$

23.5 Color and Dispersion

- Color is a *perception*, NOT a physical quantity!
- A prism *disperses* white light into various colors.
- When a particular color of light enters a prism, its color does NOT change.



23.5 Color and Dispersion

- *Different* colors are associated with light of *different* wavelengths.
- The *longest* wavelengths are perceived as *red* light; the *shortest* as *violet* light.
- What we perceive as white light is a mixture of all colors.

Color	Approximate wavelength
Deepest red	700 nm
Red	650 nm
Green	550 nm
Blue	450 nm
Deepest violet	400 nm

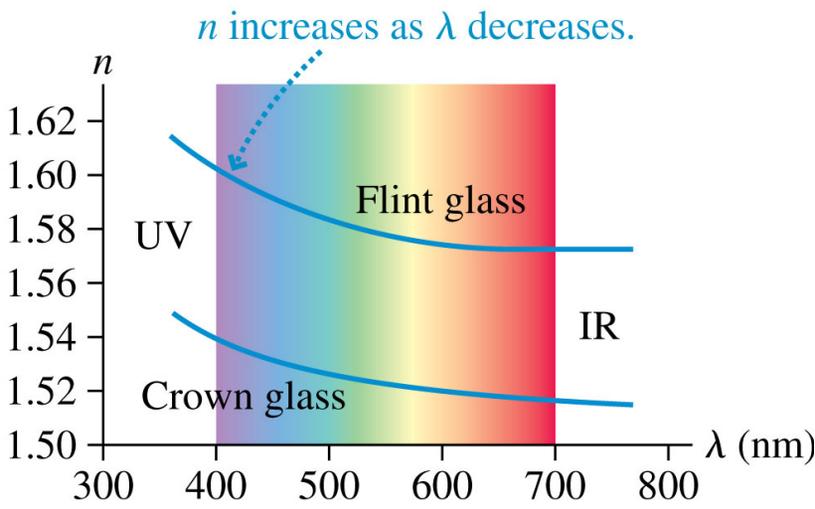
Dispersion…

- is the *slight* variation of index of refraction with wavelength.

- Below is the dispersion curves of two common glasses.

Notice:

- *n* is *larger* when the wavelength is *shorter*.



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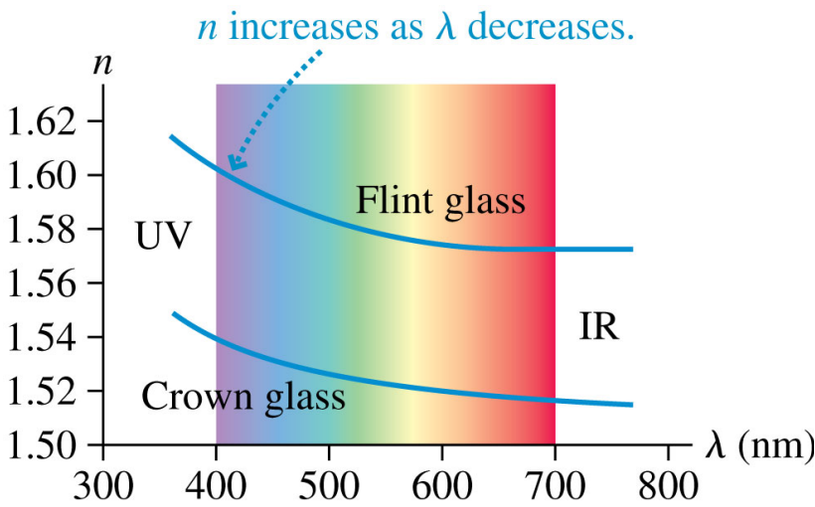
Q: Which color travels *faster* (in the material)?



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Q: Which color travels *faster* (in the material)?

Q: Which color *refracts* more?